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(56) Documents Cited
EP 0945852 A EP 0732687 A US 5581652 A
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(54) Abstract Title
Audio circuit and method for wideband to narrowband transition in a communication device

(57) A subscriber unit moving from a cell where a wideband speech channel (e.g. 8kHz) is utilised to a cell where a narrowband speech channel (e.g. 4kHz) is utilised usually experiences an immediately perceivable deterioration in audio signal quality output. This is overcome by generating a pseudo wideband signal from the received narrowband signal by analysing (68) formant components of the received signal, or by duplicating the narrowband spectral profile and reflecting (74) the profile about the narrowband Nyquist point. In the former respect, low frequency components are matched (70) against low frequency signal profiles stored in a database, and associated high frequency components are added to complete the speech signal in a manner equivalent to an 8kHz channel. During a transition period, the pseudo wideband signal is progressively band-limited (80) to the narrowband signal of the currently occupied cell.

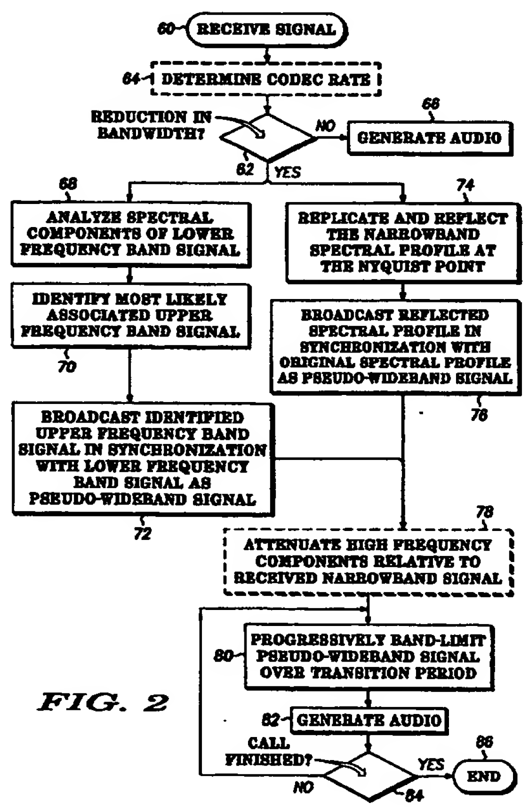

FIG. 2

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

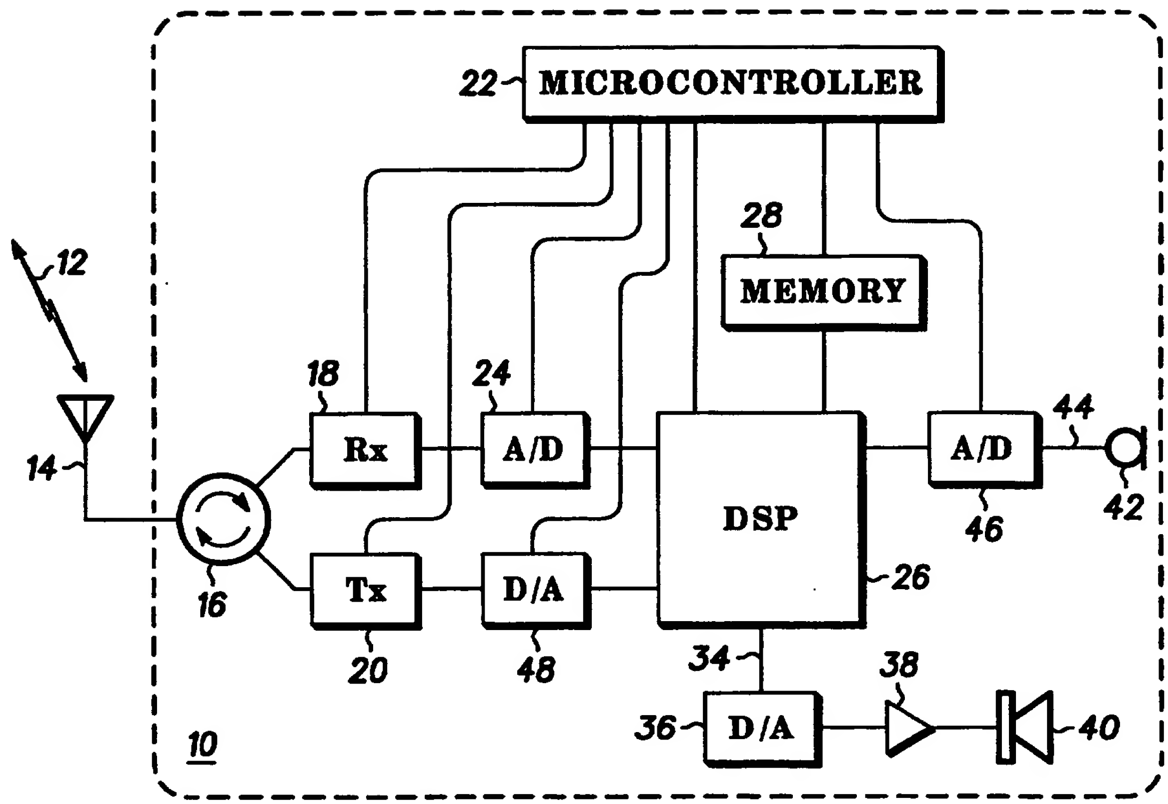
MICROCONTROLLER
22
28
MEMORY
12
18
24
Rx
A/D
44
A/D
14
DSP
42
46
16
Tx
D/A
26
20
48
34
38
36
D/A
40
10

FIG. 1

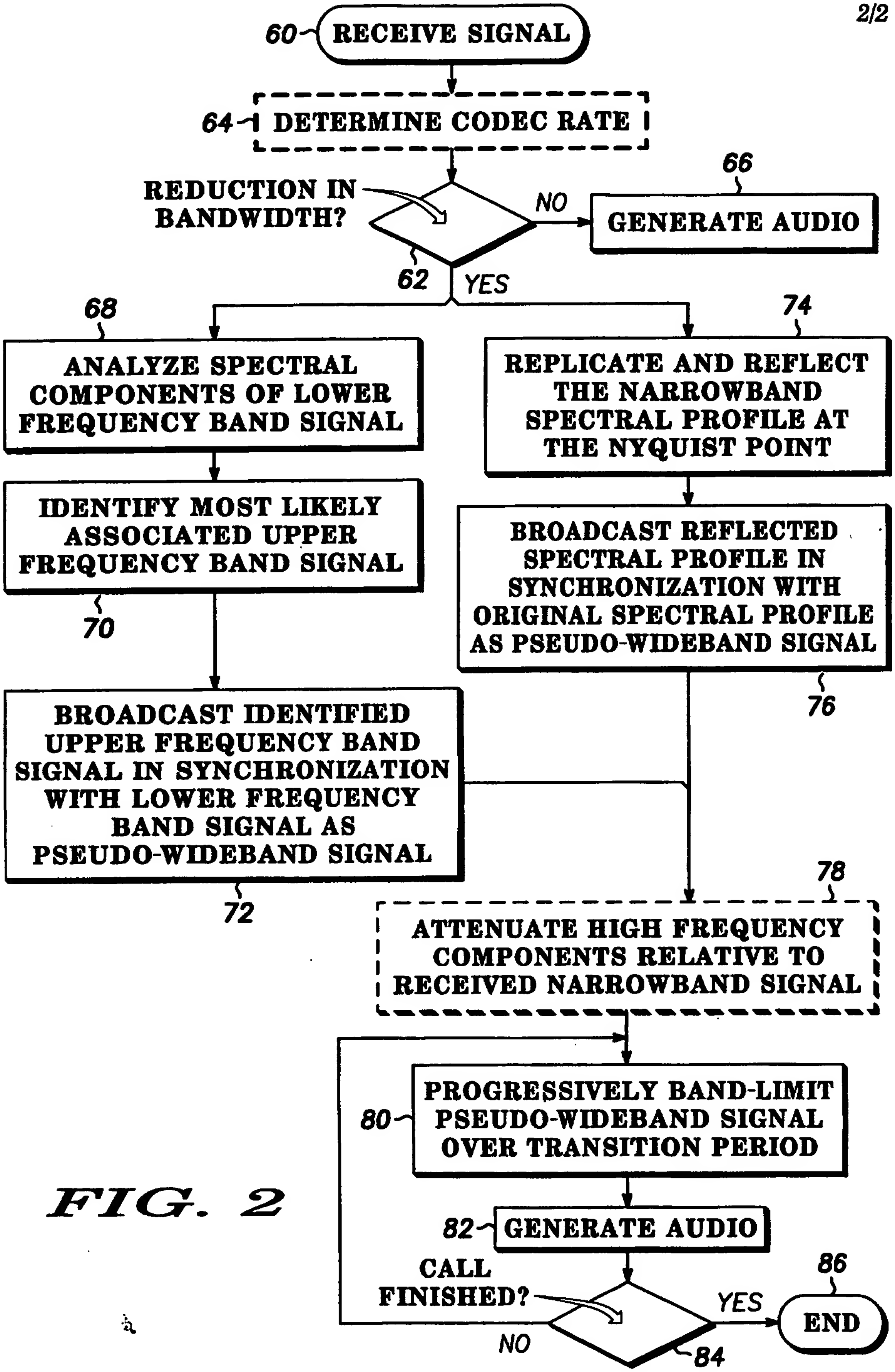
60 RECEIVE SIGNAL
64 DETERMINE CODEC RATE
REDUCTION IN BANDWIDTH?
62
NO
66 GENERATE AUDIO
YES
68 ANALYZE SPECTRAL COMPONENTS OF LOWER FREQUENCY BAND SIGNAL
IDENTIFY MOST LIKELY ASSOCIATED UPPER FREQUENCY BAND SIGNAL
70
BROADCAST IDENTIFIED UPPER FREQUENCY BAND SIGNAL IN SYNCHRONIZATION WITH LOWER FREQUENCY BAND SIGNAL AS PSEUDO-WIDEBAND SIGNAL
72
74 REPLICATE AND REFLECT THE NARROWBAND SPECTRAL PROFILE AT THE NYQUIST POINT
BROADCAST REFLECTED SPECTRAL PROFILE IN SYNCHRONIZATION WITH ORIGINAL SPECTRAL PROFILE AS PSEUDO-WIDEBAND SIGNAL
76
78 ATTENUATE HIGH FREQUENCY COMPONENTS RELATIVE TO RECEIVED NARROWBAND SIGNAL
80 PROGRESSIVELY BAND-LIMIT PSEUDO-WIDEBAND SIGNAL OVER TRANSITION PERIOD
82 GENERATE AUDIO
CALL FINISHED?
84
NO
YES
86 END

FIG. 2

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AUDIO CIRCUIT AND METHOD FOR WIDEBAND TO NARROWBAND TRANSITION IN A COMMUNICATION DEVICE

Background to the Invention

This invention relates, in general, to an audio circuit and method for maintaining a high level of perceived speech quality during wideband to narrowband operational transition in a communication device. The invention is particularly, but not exclusively, concerned with a change from a wideband speech channel to a narrowband speech channel during a handover between different modes within a telecommunications system, such as the Universal Mobile Telecommunication System [UMTS] or between other systems and UMTS.

Summary of the Prior Art

Modern telecommunications systems are structured to allow the routing of information, such as encoded speech and data, to many forms of communication device. For example, devices such as cellular radiotelephones may communicate with landline telephones, interactive Internet service providers or other cellular radiotelephones. In a cellular environment, during such communications, one or both subscriber units may move position and so transition between service providers offering differing levels of qualities of service (QoS). For example, a subscriber unit may move out of a geographical area (or 'cell') where a wideband speech channel is utilised, into a different cell where a narrowband speech channel is utilised; the cells could, in fact, be overlaid and so the transition could be between layers of a system.

As will be appreciated by the skilled artisan, communication spectrum (especially in the radio frequency domain) is limited in availability. More particularly, a service provider will only be allocated a small proportion of the spectrum in which it can provide a selective service to a multiplicity of subscriber units.

Various coding and modulation schemes have therefore been developed in an attempt to support ever increasing numbers of subscribers each tending to demand increasing levels of quality of service (QoS) with time. With limited bandwidth, therefore, strategies must also be adopted to support varying system access demands (such as those occurring through different parts of a day). Furthermore, systems may provide differential services between hierarchies of subscribers based on instantaneous demand. For example, bandwidth allocated to an on-going call could be limited/reduced when a particular cell suffers an influx of subscribers beyond its provisioned capacity. Consequently, the service provider must be resigned to either providing a reduced QoS or forego supporting additional subscribers (which is clearly undesirable from both a subscriber access standpoint and a revenue position for the service provider). Unfortunately, in the former respect, any bandwidth change causes a sudden and perceivable change in the speech quality projected to a receiving party in the call.

In the context of wideband audio, one can consider that the transmitted audio bandwidth may be 5kHz or more and probably about 7kHz, the lower cut-off frequency is likely to be around 50-70 Hz. In contrast, narrowband signals have a limited bandwidth of up to about 3.5kHz with a lower cut-off frequency of about 250 Hz (as supported by conventional wireline telephony systems, for example) and so such narrowband systems present and employing such a constrained bandwidth produces a significantly poorer audio response.

The current state-of-the-art in speech coding means that toll-quality (wireline) narrowband speech can be provided at bit rates between 5 and 8 kbps. For wideband audio, similar fidelity requires almost twice the bit rate and although this requirement is likely to reduce with time, it seems clear that wideband speech will continue to require a higher bit rate.

Given that different parts of a UMTS network(s) will provide different quality of service, it is likely that changes between wideband and narrowband codecs will

occur during calls. It is therefore desirable to produce an effective mechanism that can smooth sudden transitions of speech quality over a change in signal bandwidth.

Summary of the Invention

According to a first aspect of the present invention there is provided an audio circuit arranged to mitigate a user-perceivable change in audio signal quality arising from a transition between a relatively wideband communication environment and a relatively narrowband communication environment, the audio circuit comprising means for generating a pseudo-wideband signal determined from a spectral profile of an incident narrowband signal.

In a second aspect of the present invention there is provided a method of managing wideband to narrowband transition in a communication device, the method comprising; generating a pseudo-wideband signal determined from a spectral profile of an incident narrowband signal, thereby to mitigate a user-perceivable change in audio signal quality arising from the transition.

Advantageously, the present invention provides a system which mitigates the otherwise perceived drop in audio signal output at a receiver which accompanies a reduction in channel bandwidth assigned to a call. Over time, after such a transition from a relatively wide bandwidth to a narrowband channel, a demand placed on processing requirements in a DSP (or the like) of a receiver is reduced by gradually phasing out any bandwidth compensation that is added to offset a possibly perceived and significant step-change in audio signal output.

The present invention is generally applicable to voice telephony services and, whilst being particularly applicable to third generation cellular systems, can be employed more widely. For example, the present invention finds application in satellite systems having insufficient data rate capacity (on a channel by channel basis) to support wideband voice transmissions.

Brief Description of the Drawings

Exemplary embodiments of the present invention will now be described with reference to the accompanying drawings, in which:

FIG.1 is a block diagram of a communication device having an audio circuit that can support the various underlying inventive concepts of the preferred embodiment of the present invention; and

FIG.2 is a flow diagram illustrating preferred operating methods for wideband to narrowband transition within the communication device of FIG.1.

Detailed Description of a Preferred Embodiment

FIG. 1 illustrates a communication device 10 (such as a receiver or transceiver) adapted to support the concepts of the various embodiments of the present invention. Modulated signals 12 falling incident on an antenna 14 of the communication device 10 are isolated through a circulator 16 that serves to isolate signals from a receiver chain 18 and a transmit chain 20; this assumes that the preferred embodiment operates as a transceiver as opposed to a more simplistic receiver-only configuration. Following conventional signal recovery in the receiver chain 18, under the control of a microcontroller 22, encoded analog signals are converted to their digital counterparts in a first analog-to-digital (A/D) converter 24 before being applied to a suitable signal processor (DSP) 26, such as a neural network or fast microprocessor. The DSP 26 is responsive to the microcontroller 22, with both having accessibility to a memory 28 that serves to store operational code and data. A pseudo-wideband signal 34 is generated by, and output from, the DSP 26 to a first digital to analog (D/A) converter 36; generation of the pseudo-wideband signal according to preferred mechanisms will be described subsequently in detail. The pseudo wideband signal is amplified in amplifier 38 before being output from an audio speaker 40. The audio speaker may have a bandwidth sufficient to support top end audio signals

of approximately 20 kHz, but at least has a bandwidth capable of supporting wideband (audio) signals utilised within the system of the preferred embodiment. The DSP generally acts to support both coding/decoding functions as well as ancillary signal processing required by the present invention.

A microphone 42 (in the specific instance of a transceiver configuration) provides an electrical representation of speech input 44 to a second A/D converter 46 coupled to the DSP 26.

For completeness, FIG.1 is shown as a transceiver configuration and hence includes a second D/A 48 coupled between the DSP 26 and transmit chain 20.

In operation, the various components are responsive to control exerted by the microcontroller 22, as will be readily appreciated.

The issue addressed by the present invention relates to a perception of QoS at a subscriber unit receiving, initially, a wideband audio signal that is subsequently curtailed to a narrowband signal upon either movement of the subscriber unit into a different coverage area or the re-configuration/re-distribution by the system/network of available channel resources. In essence, the receiver of the present invention, upon detecting a change in signal bandwidth or codec rate, generates a pseudo-wideband signal determined from a spectral profile/analysis of the new incident narrowband audio signal. In a preferred embodiment, a subscriber whose QoS has, in fact, dropped by virtue of the now restricted channel bandwidth supported by the narrowband channel resource, does not indefinitely maintain the pseudo-wideband signal but preferably reduces over time the impact of synthesised frequency components beyond the Nyquist point of the narrowband signal *per se*. Such reduction is desirable since synthesis is generally processor intensive and hence potentially imposes an undesirable drain on battery capacity (if the subscriber unit is battery powered). Furthermore, such synthesis is clearly a projection of upper frequency components based on historic data, it is likely that, over time, continued use of

the generated upper frequency components will result in a user perceiving a greater degree of artificiality in the generated audio signal.

Turning to how the receiver of the preferred embodiment generates the pseudo-wideband signal from an incident narrowband channel, the present invention contemplates two preferred synthesis mechanisms (although others may be apparent to the skilled addressee). The mechanisms generally rely upon the DSP 26 undertaking spectral analysis of received narrowband signals. The purpose of the spectral analysis is to identify a pattern in frequency components within the narrowband domain that are representative or suggestive of a more complete (and hence wideband) signal. Essentially, patterns in narrowband frequency components are remnants of any initial verbal utterance filling a wider bandwidth signal. Consequently, in a first embodiment, memory 28 contains a multiplicity of pre-stored frequency profiles (e.g. spectral templates) which are constructed from a band of low frequency spectral components and an associated band of relatively high frequency (i.e. above the Nyquist point of the narrowband channel of the system in question) spectral components. Analysis by the DSP 26 of an incident narrowband signal is used to identify a most likely associated upper frequency band. The DSP 26 can then formulate the pseudo-wideband signal by using the incident narrowband signal in combination with the most likely associated upper frequency band profile stored in the memory 28. The upper band frequency profile may be broadcast from speaker 40 at a level relative or exactly aligned to that of the incident narrowband signal. Typically, the upper frequency band profile will be attenuated to mitigate any selection error.

In more detail, the system operates on the basis that speech is formed of formants which are indicative of the enunciation of sounds and leads to recognition of speech sounds by aural perception. A formant is a frequency profile of both voiced and unvoiced sounds. Each formant (or partial but significant spectral profile) in the narrowband 4kHz voice channel is matched to a similar lower frequency image stored in a database (within memory 28)

connected to the DSP 26 and the microcontroller 22. The DSP 26 operates effectively to add synthesised upper frequency components to the narrowband signal in an attempt to re-construct each formant (or similar form of audio spectral template) and hence to operate a synthesised speech signal equivalent to a wideband (e.g. 8kHz) voice channel. This estimation of higher frequency components of each formant (or audio spectral template) using lower frequency spectral components of each formant can be achieved using a mapping procedure within a neural network mapping or, alternatively, a model of the vocal tract, such as the lossless tube model. The resulting pseudo wideband quality does not exactly regenerate the original wideband speech but the subscriber should not be perturbed by the change in QoS and preferably is not able to perceive a marked difference.

After transition from wideband to narrowband service, the pseudo wideband signal is progressively band-limited to the narrowband speech signal which is actually in use. After this transition period, it is only the decoded narrowband speech which is output from audio speaker 40 to the listener.

In another embodiment, rather than using pre-stored high frequency spectral profiles, the present invention contemplates a frequency folding technique. Basically, the DSP 26 on receipt of a narrowband signal (and hence a change/restriction in bandwidth) interacts with memory 28 to replicate and reflect the narrowband spectral profile at the Nyquist point to effectively double the bandwidth of the audio signal output at the speaker 40. The replicated spectral profile, in a particular embodiment, is attenuated and most preferably attenuated at varying degrees with increasing frequency.

FIG. 2 illustrates the method steps for smoothing the sudden change in speech quality due to a transition, from a wideband signal to a narrowband signal according to preferred operating methodologies of the present invention. The process begins at block 60 when a cellular radio-telephone, or the like, receives a signal. The receiver detects a change in bandwidth 62 of the received signal,

which may be implied by detecting a change in codec rate 64. If no reduction in signal bandwidth is evident, an audio signal is generated 66 from the received signal. However, if a reduction in signal bandwidth (or change in codec rate) is detected, a pseudo-wideband signal is generated via one of two possible mechanisms. In a first preferred embodiment, the spectral components of the lower frequency band are analysed 68, and these components are compared against many pre-stored lower frequency profiles. A most likely associated upper frequency band component is identified 70 by the DSP 26. The upper frequency band component is broadcast at a level aligned to the incident narrowband signals thus generating a pseudo-wideband signal 72.

The second preferred methodology comprises the interaction of the DSP and memory to replicate and reflect 74 the narrowband spectral profile of the incoming signal at the Nyquist point. Then the reflected spectral profile is audio broadcast 76 in synchronisation with the original narrowband signal to generate the pseudo-wideband signal.

Since the frequency components of voice are generally concentrated at lower frequencies, the higher frequencies in the synthesized band become less important. Thus in both preferred embodiments the upper frequency band profile may, optionally, be attenuated 78; this is applicable to both methodologies. The next preferred step comprises the progressive band-limitation 80 of the pseudo-wideband signal over the period of transition from a wideband signal to a narrowband signal in a loop that is of fixed time duration. Consequently, over time and duration of a call, full transition to narrowband from wideband via pseudo-wideband occurs (steps 82-84). Clearly, once the call is terminated 86, then device operation returns to any pre-set default condition.

In the case of a transition from a narrowband to wideband system, then it is preferred that the change in QoS is instantaneous, although the receiver software could be configured to increase QoS (by extending the bandwidth) on a more gradual basis.

In summary, according to an underlying invention concept, a system of a preferred embodiment operates to generate a pseudo-wideband spectrum which roughly approximates to a wideband signal, which system is operational for, preferably, a limited period bridging a transition from wideband to narrowband communication.

It will be appreciated that the above description has been given by way of example only and that modifications in detail may be made within the scope of the invention. For example, whilst the present invention has been generally described in relation to a cellular radiotelephone network, such as a UMTS variable bit-rate speech coding environment, the underlying concept can be employed in a host of systems including but not limited to voice over Internet protocol (VoIP). Additionally, whilst the preferred embodiment relies upon a receiver independently identifying a change in bandwidth, it should also be appreciated that a message could be transmitted by the system in advance of a change to reduced bandwidth. Of course, it is contemplated that a pseudo-wideband signal could always be generated for a narrowband channel, even if the subscriber unit receiving the audio signal had established the call in the narrowband domain. However, as indicated, this action is likely to suggest to a user that the audio is generated artificially. In any event, a call commenced on the narrowband domain effectively does not suffer from a perceivable instantaneous drop in QoS when there is an oscillation to wideband service and back to narrowband during one call.

Claims

1. An audio circuit arranged to mitigate a user-perceivable change in audio signal quality arising from a transition between a relatively wideband communication environment and a relatively narrowband communication environment, the audio circuit comprising means for generating a pseudo-wideband signal determined from a spectral profile of an incident narrowband signal.

2. The audio circuit of claim 1, further comprising:

a memory having stored therein templates having relatively high frequency spectral components and relatively low frequency spectral components;

and wherein the means for generating further includes;

means for comparing the spectral profile of the incident narrowband signal with the relatively low frequency spectral component templates stored in the memory to identify relatively high frequency spectral components that are likely to be associated with the incident narrowband signal; and

means for combining the relatively high frequency spectral components identified as likely to be associated with the incident narrowband signal with the incident narrowband signal to produce the pseudo-wideband signal.

3. The audio circuit of claim 1, wherein the incident narrowband signal has a Nyquist point and wherein the means for generating the pseudo-wideband signal further includes means for duplicating and reflecting and then modifying the incident narrowband signal at about the Nyquist point of the incident narrowband signal, thereby to generate the pseudo-wideband signal.

4. The audio circuit according to claim 3, wherein the means for generating the pseudo-wideband signal further includes means for modifying a spectral profile of a duplicated and reflected representation of the narrowband signal.

5. The audio circuit of any preceding claim further comprising means for progressively band-limiting the pseudo-wideband signal to the incident narrowband signal over a transition period.

6. A communication device comprising the audio circuit of any preceding claim.

7. A method of managing wideband to narrowband transition in a communication device, the method comprising:

generating a pseudo-wideband signal determined from a spectral profile of an incident narrowband signal, thereby to mitigate a user-perceivable change in audio signal quality arising from the transition.

8. The method of claim 7, further comprising:

storing in memory of the communication device a multiplicity of spectral templates each having relatively high frequency spectral components associated with relatively low frequency spectral components;

comparing the spectral profile of the incident narrowband signal with the relatively low frequency spectral components stored in the memory to identify relatively high frequency spectral components that are likely to be associated with the incident narrowband signal and;

combining the relatively high frequency spectral component identified as likely to be associated with the narrowband signal with the incident narrowband signal to produce the pseudo-wideband signal.

9. The method of claim 7, wherein the incident narrowband signal has a Nyquist point and the method further comprises generating the pseudo-wideband signal by substantially duplicating the spectral profile of the incident narrowband signal, and then reflecting such duplicated spectral profile at about the Nyquist point.

10 The method of claim 9, further comprising modifying a spectral profile of a duplicated and reflected representation of the narrowband signal.

11. The method of any one of claims 7 to 10, further comprising progressively band-limiting the pseudo-wideband signal over a transition period to converge an audio output to the incident narrowband signal.

12. An audio circuit substantially as herein described with reference to the accompanying drawings.

13. A communication device substantially as herein described with reference to the accompanying drawings.

14. A method for wideband to narrowband transition substantially as herein described with reference to the accompanying drawings.

The Patent Office

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Application No:	GB 9930572.4	**Examiner:**	Martyn Dixon
Claims searched:	all	**Date of search:**	19 June 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): H4R (RPBE,RPV,RPVS,RPX)

Int Cl (Ed.7): G10L (21/02); H04Q (7/38)

Other: Online: EPODOC,WPI,JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	EP 0945852 A	(British Telecommunications)	
A	EP 0732687 A	(Matsushita)	
A	US 5581652 A	(Nippon Telegraph & Telephone)	
A	US 5455888 A	(Northern Telecom)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
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